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Optical detection of spin currents[1]

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Extensive efforts are currently being devoted to developing spintronics. Several techniques have been developed to generate pure spin currents in many materials and structures. However, there is still no method available that can be used to directly detect pure spin currents, which carry no net charge current and no net magnetization. Currently, studies of pure spin currents rely on measuring the induced spin accumulation with optical techniques or spin-valve configurations. I will discuss observation of a second-order nonlinear optical effect of pure spin currents that can be used for the non-invasive, non-destructive, and real-time imaging of pure spin currents. This effect is caused by a subtle imbalance of the Faraday rotation of electrons with opposite spin orientations [1]. In our experiment, a transient pure spin current was injected in a GaAs crystal by a quantum interference and control technique using a pair of phase-locked ultrafast laser pulses. Second- harmonic generation of an ultrafast probe pulse with a central wavelength of 1760 nm was observed [2]. We systematically studied the second-harmonic power as a function of the probe delay, probe position, spin current density, and carrier density. All the observations are consistent with a second- order nonlinear optical effect induced by the pure spin current. Since this effect does not rely on optical resonances, it can be used to detect pure spin currents in a wide range of materials with different bandstructures. Furthermore, the control of nonlinear optical properties of materials with pure spin currents may have potential applications in photonics integrated with spintronics.

[1] J. Wang, B. F. Zhu, and R. B. Liu, Phys. Rev. Lett. 104, 256601 (2010).
[2] L. K. Werake and H. Zhao, Nat. Phys. 6, 875 (2010).

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